CLAIMS

1. Apparatus for tracking an object, comprising:

a plurality of field generators, adapted to generate electromagnetic fields at different, respective frequencies in a vicinity of the object;

a radio frequency (RF) driver, adapted to radiate a RF driving field toward the object;

a wireless transponder, fixed to the object, the transponder comprising:

at least one sensor coil, coupled so that an electrical current flows in the at least one sensor coil responsive to the electromagnetic fields;

a control circuit, coupled to the at least one sensor coil so as to generate an output signal indicative of the current; and

a power coil, coupled to receive the RF driving field and to convey electrical energy from the driving field to the control circuit, and further coupled to transmit the output signal generated by the control circuit; and

a signal receiver, adapted to receive the output signal transmitted by the power coil and, responsive thereto, to determine coordinates of the object.

2. Apparatus according to claim 1, wherein the electrical current in the at least one sensor coil has frequency components at the different frequencies of the one or more field generators, and wherein the signal generated by the control circuit is indicative of the frequency components of the current.

3. Apparatus according to claim 1, wherein the one or more field generators are adapted to generate the electromagnetic fields at respective field frequencies, and the RF driver is adapted to radiate the RF driving field at a driving frequency, and wherein the one or more field generators and the RF driver are coupled to operate so that the field frequencies and driving frequency are mutually synchronized.

4. Apparatus according to claim 1, wherein the control circuit is adapted to generate the output signal so as to indicate a phase of the current flowing in the at least one sensor coil, relative to a phase of the electromagnetic fields.

5. Apparatus according to claim 1, wherein the control circuit comprises a voltage-to-frequency (V/F) converter, which is coupled to generate the output signal with an output frequency that varies responsive to the electrical current flowing in the at least one sensor coil.

6. Apparatus according to claim 1, wherein the transponder is adapted to be inserted, together with the object, into a body of a subject, while the one or more field generators and the RF driver are placed outside the body.

7. Apparatus according to claim 6, wherein the object comprises an elongate probe, for insertion into the body, and wherein the transponder is fixed in the probe so as to enable the receiver to determine the coordinates of a distal end of the probe.

8. Apparatus according to claim 6, wherein the object comprises an implant, and wherein the transponder is fixed in the implant so as to enable the receiver to determine the coordinates of the implant within the body.

9. Apparatus according to claim 8, wherein the implant comprise a hip joint implant, comprising a femur head and an acetabulum, and wherein the transponder comprises a plurality of transponders fixed respectively to the femur head and the acetabulum, and wherein the signal receiver is adapted to determine a distance between the femur head and the acetabulum responsive to the output signal from the transponders.

10. Apparatus according to claim 1, wherein the control circuit is adapted to operate powered solely by the electrical energy conveyed thereto by the power coil.

11. Apparatus for tracking an object, comprising:

a radio frequency (RF) driver, adapted to radiate a RF driving field toward the object at a driving frequency;

one or more field generators, adapted to generate electromagnetic fields in a vicinity of the object at respective field frequencies, in synchronization with the driving frequency;

a wireless transponder, fixed to the object, the transponder comprising:

at least one sensor coil, coupled so that an electrical current flows in the at least one sensor coil responsive to the electromagnetic fields;

a control circuit, coupled to the at least one

sensor coil so as to generate an output signal indicative of the current; and

a power coil, coupled to receive the RF driving field and to convey electrical energy from the driving field to the control circuit, and further coupled to transmit the output signal generated by the control circuit; and

a signal receiver, adapted to receive the output signal transmitted by the power coil and, responsive thereto, to determine coordinates of the object.

12. Apparatus according to claim 11, wherein the control circuit is coupled to receive a frequency synchronization signal from the power coil, responsive to the RF driving field, and to apply the frequency synchronization signal in generating the output signal.

13. Apparatus according to claim 11, wherein the driving frequency of the RF driving field is an integer multiple of the field frequencies of the electromagnetic fields of the one or more field generators.

14. Apparatus according to claim 11, wherein the control circuit is adapted to generate the output signal, responsive to the synchronization of the field frequencies with the driving frequency, so as to indicate a phase of the current flowing in the at least one sensor coil, relative to a phase of the electromagnetic fields.

15. Apparatus according to claim 11, wherein the control circuit comprises a voltage-to-frequency (V/F) converter, which is coupled to generate the output signal with an output frequency that varies responsive to the electrical

current flowing in the at least one sensor coil.

16. Apparatus according to claim 11, wherein the transponder is adapted to be inserted, together with the object, into a body of a subject, while the one or more field generators and the RF driver are placed outside the body.

17. Apparatus for tracking an object, comprising:

a radio frequency (RF) driver, adapted to radiate a RF driving field toward the object;

one or more field generators, adapted to generate electromagnetic fields in a vicinity of the object;

a wireless transponder, fixed to the object, the transponder comprising:

at least one sensor coil, coupled so that an electrical current flows in the at least one sensor coil responsive to the electromagnetic fields;

a control circuit, coupled to the at least one sensor coil so as to generate an output signal indicative of an amplitude of the current and of a phase of the current relative to a phase of the electromagnetic fields; and

a power coil, coupled to receive the RF driving field and to convey electrical energy from the driving field to the control circuit, and further coupled to transmit the output signal generated by the control circuit; and

a signal receiver, adapted to receive the output signal transmitted by the power coil and, responsive to the amplitude and phase of the current indicated by the

output signal, to determine an orientation of the object.

18. Apparatus according to claim 17, wherein the at least one sensor coil comprises a single sensor coil, and wherein the signal receiver is adapted, responsive to the indicated phase of the current, to determine a direction of the orientation of the transponder.

19. Apparatus according to claim 17, wherein the control circuit comprises a voltage-to-frequency (V/F) converter, which is coupled to generate the output signal with an output frequency that varies responsive to the electrical current flowing in the at least one sensor coil.

20. Apparatus according to claim 17, wherein the transponder is adapted to be inserted, together with the object, into a body of a subject, while the one or more field generators and the RF driver are placed outside the body.

21. Apparatus for tracking an object, comprising:

a radio frequency (RF) driver, adapted to radiate a RF driving field toward the object;

one or more field generators, adapted to generate electromagnetic fields in a vicinity of the object;

a wireless transponder, fixed to the object, the transponder comprising:

at least one sensor coil, coupled so that an electrical current flows in the at least one sensor coil responsive to the electromagnetic fields;

a voltage-to-frequency (V/F) converter, coupled to the at least one sensor coil so as to generate an output signal with an output frequency that varies

responsive to an amplitude of the electrical current flowing in the at least one sensor coil; and

a power coil, coupled to receive the RF driving field and to convey electrical energy from the driving field to the control circuit, and further coupled to transmit the output signal generated by the control circuit; and

a signal receiver, adapted to receive the output signal transmitted by the power coil and, responsive to the output frequency, to determine coordinates of the object.

22. Apparatus according to claim 21, wherein the transponder is adapted to be inserted, together with the object, into a body of a subject, while the one or more field generators and the RF driver are placed outside the body.

23. A wireless position transponder for operation inside a body of a subject, the transponder comprising:

at least one sensor coil, coupled so that an electrical current flows in the at least one sensor coil responsive to one or more electromagnetic fields applied to the body in a vicinity of the transponder;

a voltage-to-frequency (V/F) converter, coupled to the at least one sensor coil so as to generate an output signal with an output frequency that varies responsive to an amplitude of the electrical current flowing in the at least one sensor coil, such that the output frequency is indicative of coordinates of the transponder inside the body; and

a power coil, adapted to receive a radio frequency (RF) driving field applied to the body in the vicinity of the transponder, and coupled to convey electrical energy from the driving field to the control circuit, and further coupled to transmit the output signal generated by the control circuit so that the signal can be received by processing circuitry outside the body for use in determining the coordinates.

24. A transponder according to claim 23, wherein the sensor coil, V/F converter and power coil are together adapted to be fixed inside an elongate probe, for insertion into the body, so as to enable the processing circuitry to determine the coordinates of a distal end of the probe.

25. A transponder according to claim 23, wherein the sensor coil, V/F converter and power coil are together adapted to be fixed inside an implant, so as to enable the processing circuitry to determine the coordinates of the implant within the body.

26. A transponder according to claim 23, wherein the V/F converter is adapted to operate powered solely by the electrical energy conveyed thereto by the power coil.

27. A method for tracking an object, comprising:

positioning a plurality of field generators so as to generate electromagnetic fields at different, respective frequencies in a vicinity of the object;

positioning a radio frequency (RF) driver to radiate a RF driving field toward the object;

fixing to the object a wireless transponder

comprising at least one sensor coil and a power coil, so that an electrical current flows in the at least one sensor coil responsive to the electromagnetic fields;

receiving the RF driving field using the power coil so as to derive electrical energy therefrom;

generating an output signal at the wireless transponder indicative of the current flowing in the sensor coil, using the electrical energy derived from the RF driving field by the power coil;

transmitting the output signal from the wireless transponder using the power coil; and

receiving and processing the output signal to determine coordinates of the object.

28. A method according to claim 27, wherein the electrical current in the at least one sensor coil has frequency components at the different frequencies of the one or more field generators, and wherein generating the output signal comprises generating the output signal responsive to the frequency components of the current.

29. A method according to claim 27, wherein positioning the one or more field generators and the RF driver comprises synchronizing respective field frequencies of the one or more field generators with a driving frequency of the RF driver.

30. A method according to claim 27, wherein generating the output signal comprises producing the output signal so as to indicate a phase of the current flowing in the at least one sensor coil, relative to a phase of the electromagnetic fields.

31. A method according to claim 27, wherein generating the output signal comprises generating the signal with an output frequency that varies responsive to an amplitude of the electrical current flowing in the at least one sensor coil.

32. A method according to claim 27, and comprising inserting the transponder, together with the object, into a body of a subject, wherein positioning the plurality of the field generators and the RF driver comprises placing the one or more field generators and the RF driver outside the body.

33. A method according to claim 32, wherein the object comprises an elongate probe, for insertion into the body, and wherein fixing the transponder to the object comprises fixing the transponder in the probe, and wherein receiving and processing the output signal comprises determining the coordinates of a distal end of the probe in the body.

34. A method according to claim 32, wherein the object comprises an implant, and wherein fixing the transponder to the object comprises fixing the transponder to the implant, and wherein receiving and processing the output signal comprises determining the coordinates of the implant within the body.

35. A method according to claim 32, wherein the implant comprise a hip joint implant, comprising a femur head and an acetabulum, and wherein fixing the transponder comprises fixing a plurality of transponders respectively to the femur head and the acetabulum, and wherein

determining the coordinates of the implant comprises determining a distance between the femur head and the acetabulum responsive to the output signal from the transponders.

36. A method according to claim 35, wherein determining the distance comprises finding the distance using the transponders during both intraoperative and post-operative periods.

37. A method according to claim 27, wherein generating the output signal comprises operating the transponder powered solely by the electrical energy derived from the RF driving field by the power coil.

38. A method for tracking an object, comprising:

positioning a radio frequency (RF) driver to radiate a RF driving field toward the object at a driving frequency;

positioning one or more field generators so as to generate electromagnetic fields in a vicinity of the object at respective field frequencies, in synchronization with the driving frequency;

fixing to the object a wireless transponder comprising at least one sensor coil and a power coil, so that an electrical current flows in the at least one sensor coil responsive to the electromagnetic fields;

receiving the RF driving field using the power coil so as to derive electrical energy therefrom;

generating an output signal at the wireless transponder indicative of the current flowing in the sensor coil, using the electrical energy derived from the

RF driving field by the power coil;

transmitting the output signal from the wireless transponder using the power coil; and

receiving and processing the output signal to determine coordinates of the object.

39. A method according to claim 38, wherein generating the output signal comprises receiving a frequency synchronization signal from the power coil, responsive to the RF driving field, and applying the frequency synchronization signal in generating the output signal.

40. A method according to claim 38, wherein the driving frequency of the RF driving field is an integer multiple of the field frequencies of the electromagnetic fields of the one or more field generators.

41. A method according to claim 38, wherein generating the output signal comprises producing the output signal responsive to the synchronization of the field frequencies with the driving frequency, so as to indicate a phase of the current flowing in the at least one sensor coil, relative to a phase of the electromagnetic fields.

42. A method according to claim 38, wherein generating the output signal comprises generating the signal with an output frequency that varies responsive to an amplitude of the electrical current flowing in the at least one sensor coil.

43. A method according to claim 38, and comprising inserting the transponder, together with the object, into a body of a subject, wherein positioning the RF driver

and the one or more field generators comprises placing the RF driver and the one or more field generators outside the body.

44. A method for tracking an object, comprising:

positioning a radio frequency (RF) driver to radiate a RF driving field toward the object;

positioning one or more field generators so as to generate electromagnetic fields in a vicinity of the object;

fixing to the object a wireless transponder comprising at least one sensor coil and a power coil, so that an electrical current flows in the at least one sensor coil responsive to the electromagnetic fields;

receiving the RF driving field using the power coil so as to derive electrical energy therefrom;

generating an output signal at the wireless transponder indicative of an amplitude of the current flowing in the at least one sensor coil and of a phase of the current relative to a phase of the electromagnetic fields, using the electrical energy derived from the RF driving field by the power coil;

transmitting the output signal from the wireless transponder using the power coil; and

receiving the output signal, and processing the amplitude and phase of the current indicated by the output signal to determine an orientation of the object.

45. A method according to claim 44, wherein the at least one sensor coil comprises a single sensor coil, and wherein processing the amplitude and the phase comprises

determining a direction of the orientation of the transponder responsive to the indicated phase of the current.

46. A method according to claim 44, wherein generating the output signal comprises generating the signal with an output frequency that varies responsive to the electrical current flowing in the at least one sensor coil.

47. A method according to claim 44, and comprising inserting the transponder, together with the object, into a body of a subject, wherein positioning the RF driver and the one or more field generators comprises placing the RF driver and the one or more field generators outside the body.

48. A method for tracking an object, comprising:

positioning a radio frequency (RF) driver to radiate a RF driving field toward the object;

positioning one or more field generators so as to generate electromagnetic fields in a vicinity of the object;

fixing to the object a wireless transponder comprising at least one sensor coil and a power coil, so that an electrical current flows in the at least one sensor coil responsive to the electromagnetic fields;

receiving the RF driving field using the power coil so as to derive electrical energy therefrom;

generating an output signal at the wireless transponder having an output frequency that varies responsive to an amplitude of the current flowing in the at least one sensor coil, using the electrical energy

derived from the RF driving field by the power coil;

transmitting the output signal from the wireless transponder using the power coil; and

receiving and processing the output signal to determine coordinates of the object, responsive to the output frequency.

49. A method according to claim 48, and comprising inserting the transponder, together with the object, into a body of a subject, wherein positioning the RF driver and the one or more field generators comprises placing the RF driver and the one or more field generators outside the body.